CONTROL SYSTEMS
(AEIE 2204)

Time Allotted : 3 hrs **Full Marks : 70**

Figures out of the right margin indicate full marks.

Candidates are required to answer Group A and any 5 (five) from Group B to E, taking at least one from each group.

Candidates are required to give answer in their own words as far as practicable.

Group – A
(Multiple Choice Type Questions)

1. Choose the correct alternative for the following: **10 × 1 = 10**

(i) If the number of open loop poles and zeros of a system are 5 and 2 respectively, the number of root locus branches terminating at infinity is
(a) 5 (b) 3 (c) 4 (d) 0.

(ii) The steady state error for a type-2 system subjected to a unit ramp input is
(a) 2 (b) 0 (c) infinity (d) 1.

(iii) If the system transfer function is $T(s) = 1/ (s^3 + 4s^2 + 5s + 2)$, the number of state variables required to represent the system is
(a) 2 (b) 4 (c) 5 (d) 3.

(iv) Which of the following can be used as an error detector in a control system?
(a) Synchro (b) Field controlled dc servomotor
(c) Armature controlled dc servomotor (d) ac servomotor.

(v) The damping ratio of the second order system $2d^2y/dt^2 + 4dy/dt + 8y = 8x$ is
(a) 0.1 (b) 0.25 (c) 1 (d) 0.5.

(vi) The Nyquist plot of a unity feedback system having 2 open loop poles and 1 open loop zero in the right side of the s-plane encircles (-1 + j0) point once in counter-clockwise direction in GH plane. The number of closed loop poles of the system in the right hand side of s plane is
(a) 2 (b) 1 (c) 0 (d) 3.

(vii) A system has a pole at s = 0. The unit step response of it
(a) linearly increases with time (b) exponentially increases with time
(c) exponentially decreases with time (d) linearly decreases with time.

(viii) The Bode plot of a system is used to specify
(a) absolute stability (b) relative stability
(c) time response (d) none of these can be predicted.

(ix) A system having transfer function G(S) = $\frac{1}{2(s+0.5)}$ is subjected to a unit step input, the steady state value of the output is

(a) 1 (b) 2 (c) 1/2 (d) 1/10

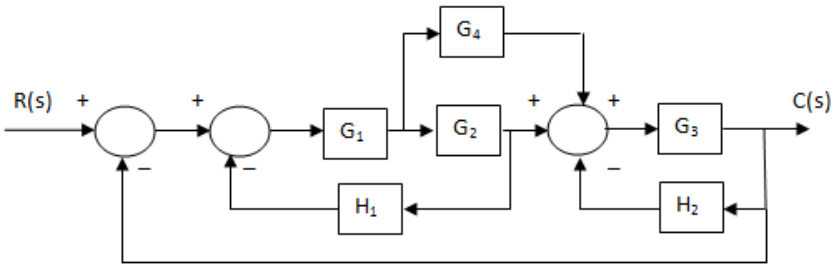
(x) The type of a transfer function denotes the number of

(a) zeros at origin (b) poles at infinity

(c) poles at origin (d) none of these.

Group- B

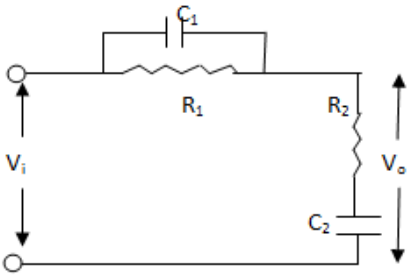
2. (a)



Find out the overall transfer function of the system for the given block diagram using block reduction technique. [(CO2)(Analyze/IOCQ)]

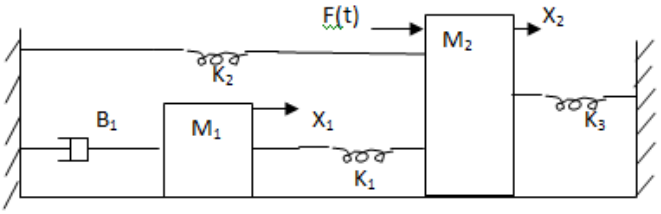
(b) For the same block diagram as mentioned in the previous question draw the signal flow graph and hence find the overall transmittance using Mason's gain formula. [(CO2)(Evaluate/HOCQ)]

(c) Find the transfer function of the system given below. [(CO1) (Analyze/IOCQ)]



6 + 4 + 2 = 12

3. (a)



Represent the given mechanical system in terms of differential equations. [(CO1)(Analyze/IOCQ)]

(b) Find the transfer function $X_2(s)/ F(s)$, where F(t) is the applied force and $X_2(t)$ is the displacement, as shown in the above figure. [(CO1)(Evaluate/HOCQ)]

(c) Find out the overall transfer function and draw the block diagram of armature controlled dc servo motor considering angular shift of the shaft as output, and applied voltage to the armature as input. [(CO2)(Analyse/IOCQ)]

3 + 4 + 5 = 12

Group - C

4. (a) The open loop transfer function of a unity feedback system is G(s) = k / [s(Ts+1)] .
Find the natural frequency of oscillation and damping ratio of the system in terms of k and T. [(CO4)(Evaluate/HOCQ)]

(b) For the above system by what factor the gain should be multiplied so that the damping ratio is increased from 0.3 to 0.9. [(CO2)(Evaluate/HOCQ)]

(c) Consider the characteristics equation of a control system given by

$$s^6+s^5-2s^4-3s^3-7s^2-4s-4=0.$$

Show that the following three conditions are satisfied:
(i) The system has three poles in the left half of the s plane.
(ii) The system has four poles symmetric about the origin.
(iii) The system has two poles on the jw axis. [(CO4)(Evaluate/HOCQ)]

4 + 2 + 6 = 12

5. (a) For a unity feedback system having open loop transfer function G(s) = k/[s(s^2 + 8s + 32)], find the centroid of asymptotes, asymptotic angles and breakaway points. [(CO4)(Evaluate/HOCQ)]

(b) For the above system find out the angle of departure or arrival and intersecting points of root locus with the imaginary axis. [(CO4)(Analyze/IOCQ)]

(c) Hence sketch the root locus plot on the graph paper and comment on the stability of the system. [(CO4)(Analyze/IOCQ)]

4 + 4 + 4 = 12

Group - D

6. (a) Construct the Bode plot for a unity feedback control system having open loop transfer function G(s) = 1250 /[s (s + 50)(s+25)]. [(CO5)(Analyze/IOCQ)]

(b) From the above Bode plot find the gain margin, phase margin, gain cross-over frequency and phase cross-over frequency. [(CO5)(Evaluate/HOCQ)]

(c) From the above findings conclude on the stability of the system. [(CO5)(Remember/LOCQ)]

7 + 4 + 1 = 12

7. (a) For a unity feedback system having open loop transfer function G(s) = k / [s(4s +1)], draw the Nyquist contour in s-plane and hence map each of the segments in GH plane with necessary calculations. [(CO5)(Evaluate/HOCQ)]

(b) Hence draw the Nyquist plot in GH plane. [(CO5)(Understand/LOCQ)]

(c) Write the Principle of Argument and find out all the parameters of it from the Nyquist plot Obtained and comment on the closed loop stability of the system. [(CO5)(Remember/LOCQ)]

6 + 3 + 3 = 12

Group - E

8. (a) In the state space model of a system, matrix A is given by,

$$A = \begin{bmatrix} -1.2653 & -0.1025 \\ 2.5830 & -0.3056 \end{bmatrix}$$

Find the stability of the system. [(CO6)(Evaluate/HOCQ)]

(b) The transfer function of a system is Y(s)/ U(s) = 1/ (s^2 + s +3). Find the state equation and output equation of the system using state variable analysis. [(CO6)(Analyze/IOCQ)]

(c) Hence draw the state block diagram of the system. [(CO6)(Analyze/IOCQ)]

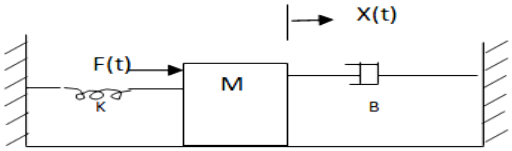
3 + 6 + 3 = 12

9. (a) In the state variable model of a linear time invariant system, matrices are

$$A = \begin{bmatrix} -2 & 4 \\ 2 & -1 \end{bmatrix} \quad B = \begin{bmatrix} 0 \\ 1 \end{bmatrix} \quad C = \begin{bmatrix} 1 & 0 \end{bmatrix} \quad D = 0$$

Check the controllability and observability of the system. [(CO6)(Evaluate/HOCQ)]

(b)



Show the free body diagram of mass M from above mass-spring-damper system. [(CO6)(Understand/LOCQ)]

(c) Find out the state matrix, input matrix and output matrix of the above system. [(CO6)(Evaluate/HOCQ)]

5 + 3 + 4 = 12

Cognition Level	LOCQ	IOCQ	HOCQ
Percentage distribution	10.42	41.66	47.92

Course Outcome (CO):

After the completion of the course students will be able to

1. Develop mathematical model of physical systems in forms of differential equation and transfer function.
2. Represent the systems using block diagram and signal flow graph models.
3. Investigate the time response of systems and calculate performance indices.
4. Apply the concept of stability in s-domain by using Routh stability criterion and root locus technique.
5. Analyze frequency response and stability of linear systems using different stability criterion.
6. Understand the concept of state variable analysis and compensation techniques for design.

*LOCQ: Lower Order Cognitive Question; IOCQ: Intermediate Order Cognitive Question; HOCQ: Higher Order Cognitive Question